Amp It Up! Engineering/Technology and Industry Lesson Extension

Teacher Name(s), School and District: Stephen Gruber, Beverly High School

Course Name: Physics and Electronics (applicable to both courses at all levels)

Lesson/Unit Name: Supplemental Lesson Plan for any Unit

Science or Education Topic(s): The Physics of Integrated Circuits Manufacturing

Engineering Technology Industry Related Field/Activity: Manufacturing/Design

When Taught: Spring 2016

Abstract: In 200 words or less, please provide a summary of your objectives, implementation, and the results of your implementation.

Integrated Circuit manufacturing is a STEM-centric activity that employees a wide range of STEM careers including Physics, Engineering, Computer Science, and Chemistry. This lesson plan provides a basic overview of the IC manufacturing process, an opportunity to do some cross-discipline engineering design, and an assignment to research a career of the student's choice related to this field.

Objectives and assessment: Using the table below, identify at least 3-5 learning objectives (content and/or pedagogical) and describe how each will be assessed.

Objectives *By the end of this lesson/unit, the students will be able to:*	**Assessment** *How was the objective assessed? List the example of formative or summative assessment.*
Explain qualitatively how electrical and magnetic force fields can be used to selectively accelerate, centripetally redirect, and “clean” an Ion stream.	PHET lab, Read and discuss Mass Spectrometry intro, then a formative assessment.. Videos, group challenge: to make an Ion “Ray Gun” for Ion implantation, then a formative assessment.
Explain the basic steps in the Integrated Circuit manufacturing process.	Discussion. Formative Assessment.
Explain primary careers available in high-value electronics manufacturing. Also understand education and qualification required for those careers.	Research, short essay, and presentation explaining which of these careers are available in an electronics manufacturing company of the student's choice.

Engineering/Technology Link: Please check the appropriate box(es) in question 1. And provide a brief answer to question 2.:

1. How did you *introduce* engineering/ technology concepts or the company/industry focus in your course? Check the appropriate box(es) or choose Other.

   XXX Defined terms (science, engineering, technology)

   XXX Described the engineering design process

   ☐ Engineering design challenge related to industry

   XXX Overview of the company

   ☐ Challenge based on 'industry specific' area of focus (manufacturing process, quality control, measurement, development, teamwork etc.)

   xxx Other: _Presentation on Integrated Circuits Manufacturing Process___

2. After introducing the concepts, what did/will the students do to explore and apply the engineering/technology and industry specific concepts? (include information about the actual activity students did, discussions they had, or instructional strategies you used)

   - PHET lab – Electric Field Hockey. Exploring Coulomb Forces.
   - Read and discuss in a small group: Mass Spectrometry Intro (jeolnovice.pdf)
   - Videos on:
     - P-N junction introduction including doping
     - Integrated Circuit manufacturing process
   - Large group discussion – how might an approach similar to Mass Spectrometry be used to make an Ion "Ray Gun" for doping IC's?
   - Formative Assessment on integrated circuit manufacturing process
   - Internet research on the student's choice of an electronics manufacturer and submission of a formative essay.
   - Short presentations by students to students on their research essays.

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Level of Inquiry: Which of the following best describes the level of inquiry (adapted from Bell 2005) you used for this lesson/unit? Check the appropriate level.

XX Structured inquiry: Instructor provides question and procedure. Students determine the results based on given procedures.

XX Guided inquiry: Instructor provides question. Students design procedure and determine the results.

☐*Open inquiry*: Students investigate their own research question. Students design procedures and implement the procedure on their own.

Lesson Extension Plan:

Title/Topic: Physics and Engineering Applied to make amazing electronic devices
Time (minutes): 84 min
Company Name and brief Description: Varian Semiconductor Equipment Division of Applied Materials Corp. Leading provider of Ion Implantation equipment used in the semiconductor industry.
Overview of the Lesson: Introduction to semiconductors and their manufacturing processes.
Standard(s)/Unit Goal(s) to be addressed in this lesson: **Physics 4.3 Describe conceptually the attractive or repulsive forces between objects relative to their charges and the distance between them (Coulomb's law).** **Technology/Engineering 1.2 The engineering design process is used to solve problems, advance society, and modify technologies, objects, and processes.**
Essential Question(s) addressed in this lesson: What are examples of Physics and Engineering skills needed to produce my favorite electronics devices?
Objectives **1. Explain qualitatively how electrical and magnetic force fields can be used to selectively accelerate, centripetally redirect, and "clean" an Ion stream.** **2. Explain the basic steps in the Integrated Circuit manufacturing process.** **3. Explain primary careers available in high-value electronics manufacturing. Also understand education and qualification required for those careers.**
Link to Industry: Electronics, Manufacturing, Engineering, ComputerScience.
What students should know and be able to do before starting this lesson: Qualitative Physics and/or chemistry exposure to electric forces acting on Ions and basic magnetism.

Instructional Materials/Resources/Tools: PHET lab, YouTube videos, Mass Spectometry Intro paper, computers and Internet for career research,
Lesson Delivery
Lesson Opening – Pith ball, plastic rod, and wool or fur for demonstrating Coulomb forces.
During the Lesson (activities/labs/challenges) – PHET lab, videos, group discussions, group design challenge, career research, presentations.
Lesson Closing – Formative Assessments
Assessment
Student Assessment: Lab reports, design draft, essay , presentation, formative assessments.
Delivery Assessment: Student learning assessed by Student Assessments.

Additional resources and assessments: List the attachments here.
Attachments should include handouts, readings (with references), lab write-ups, rubrics, exams/quizzes, and/or other similar materials.

PHET Lab: Electric Field Hockey

P-N junction with doping video: https://www.youtube.com/watch?v=IcrBqCFLHIY

Semiconductor Manufacturing Intro: https://www.youtube.com/watch?v=qm67wbB5GmI

Mass Spectrometry intro paper:
http://www.research.uky.edu/core/massspec/jeolnovice.pdf

Following Quiz adapted from material for course EE3143 found at www.ohio.edu:

Integrated Circuits Formative Assessment

Please answer the following questions:

1. What features of integrated circuits have enabled them to revolutionize modern electronics?

Soln.: - Small Size, Low cost of manufacturing and low power.

3. How is solid crystal silicon formed from molten silicon?

Soln.: - A seed crystal is dipped into a vat containing molten silicon and then slowly pulled out while rotating the seed and the vat containing the molten silicon in opposite directions. The molten silicon replicates the structure of the seed and cools as it is extracted from the vat.

4. What makes a material a semiconductor? What are dopants?

Soln.: - A semiconductor is a material that has electrical properties (conductivity) between a conductor and an insulator. It behaves as a insulator at low temperature and as a conductor at high temperature. Dopants are the impurities added to semiconductors to better control their electrical properties.

5. Integrated circuits contain a maze of interconnected, microscopic switches called transistors. What is the function of these transistors?

Soln.: - The transistors either act like switches by conducting or blocking signals or they act like amplifiers by amplifying the input signals.

6. Describe the process by which integrated circuits are designed. How do the designs make the transition from computer to chip?

Soln.: - IC design is performed using CAD tools. IC layout is drawn and checked for accuracy using various CAD tools. A mask designer uses the layout to create a mask design and this mask design is fed to another computer that controls instruments that are used to etch the design onto wafer.

7. Why must the environment in which integrated circuits are manufactured be as dust-free as possible?

Soln.: - Presence of even a small amount of dust in the manufacturing facility might change the dopant concentration in the IC being manufactured. This can lead to defective chips or chips with incorrect electrical properties.

8. What purpose does photolithography serve in the integrated circuit manufacturing process? Explain this procedure.

Soln.: - Photolithography is a process used to mark the regions for transferring the design from the mask to the wafer. During photolithography a light sensitive material is uniformly applied to the wafer. The mask is properly aligned on the wafer and light is used to transfer the mask pattern onto the wafer. The resist reacts to the light and the exposed area (if positive photoresist or unexposed area if negative photoresist) is dissolved and pattern etched onto the wafer,

9. How are dopant ions added to wafers?

Soln.: - Dopant ions are accelerated and bombarded onto wafers so that they embed themselves in the wafer.

10. What feature of the integrated circuit allows modern computers to be very fast? What role does insulating material between transistors play?

Soln.: - Small size and high density are the features of the IC that allow modern computers to be very fast. Having insulating material between transistors allows for higher density of transistors and the electrical contacts in a IC.

11. How are electrical circuits incorporated into the chip? How is the chip connected to wires from the outside world?

Soln.: - Wiring layers, created using photolithography and etching, are used to create the circuits. The circuit is then connected to the pad frame using gold wires and the pads are connected to the outside using aluminum pads on the edges of the chip.